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AN AURORAL IONOSPHERIC INVESTIGATION
A PRELIMINARY REPORT ON ELECTRON DENSITY PROFILES

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An Auroral Ionospheric Investigation: A Preliminary Report on Electron Density Profiles

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Upper Air Physics Branch
Space Science Division

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This is the first in a series of reports dealing with the results of a major NASA program coordinating rocket, balloon, and ground-based auroral studies at Poker Flat, Alaska. The program, carrying the code name AUROROZONE, was designed to study the effects of energetic particle precipitation on the ionosphere and the coupling of particle energy to lower altitudes through x-ray bremmstrahlung radiation. The interest in lower altitude effects focused on changes in ozone, electrical conductivity and temperature.

(Continues)

20. Abstract (Continued)

Scientists from several universities and government laboratories participated in this cooperative effort. These included Utah State University, Stanford Research Institute, Denver University, University of Washington, Atmospheric Science Laboratory (WSMR), University of Texas/El Paso, the Naval Research Laboratory, the University of Alaska, and the Goddard Space Flight Center.

This initial report presents the preliminary findings on the ionospheric plasma state in the 60-230 km region as determined by the Naval Research Laboratory's pulsed plasma probe experiment carried on the Nike-Tomahawk payloads.

CONTENTS

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AN AURORAL IONOSPHERIC INVESTIGATION:
A PRELIMINARY REPORT ON ELECTRON DENSITY PROFILES

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I. INTRODUCTION

On 21 and 23 September 1976, two Nike-Tomahawk payloads were launched from Poker Flat Research Range (Alaska) to study the effects of energetic particle precipitation on the ionosphere and the coupling of particle energy to lower altitudes through X-ray bremsstrahlung radiation.

The payloads NASA 18.178 and 18.179, illustrated in Figure 1, were instrumented with Geiger-Mueller tubes, shielded scintillation detectors, and pulsed plasma probes to determine the incident electron energy distribution, the incident and excited X-ray radiation, and the zeroth order plasma condition and state of instability.

These Nike-Tomahawk launches were part of a coordinated operation involving pre- and post-flight soundings by other rockets of stratospheric and mesospheric ozone and conductivity. The launches were also coordinated with Chatanika radar, all-sky camera and ground-based photometric observations, and with experiments aboard stratospheric balloons near 40 km. The ground-based and balloon-borne observations permitted continuous monitoring of background cosmic ray radiation, energetic X-ray, and overall auroral development and morphology during the entire launch sequence.

The timing of the launches also provided opportunities for some correlative measurements between directly observed ionospheric irregularities and scintillation spectrum as measured on Wideband Satellite during passes of convenience.

This report will focus on the NRL contribution to the overall program, the direct measurement of the ionospheric

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plasma state as determined by two on-board pulsed-plasma-probes (P^3). To facilitate and expedite experimenter interaction and provide preliminary data upon which particular regions of interest in space and time can be identified, we present in this report our quick-look results on relative electron density profiles. Final analyses will completely determine the absolute electron density, temperature, and density fluctuation power spectrum over the entire trajectory.

II. THE NRL PULSED PLASMA PROBE (P^3) EXPERIMENT

Since the P^3 technique has been described in detail elsewhere (1-4), only a brief account will be given here in order to facilitate an understanding of the data.

Each of the two probes shown in Figure 1 has simultaneously applied to it a voltage function like that illustrated in Fig. 2. (An expanded view of the pulses and current sampling intervals are shown in Fig. 3.) The types of probe operation cover conventional Langmuir probe diagnostics (the continuous sawtooth function in Fig. 2A) and pulsed-probe diagnostics (pulse-modulated sawtooth function in Fig. 2B), with the latter having greater intrinsic capabilities for plasma studies than the former (1-4). The electronics automatically generate a continuing chain of sweeps comprising 2 continuous mode sweeps followed by eight pulse-mode sweeps. (The continuous sweeps are only included to study the hysteresis effects which can distort the conventional Langmuir procedure.)

The currents sampled on the sawtooth envelope are used to generate the conventional current-voltage characteristics from which absolute electron density and temperature are determined (5). The interpulse sampling of currents ($\equiv I_B$) at the fixed baseline voltage V_B tracks density variations which may occur during the sweep time T_S, and provides the data for determination of electron density fluctuation power spectra. The I_B values provide high resolution measurements (~1 msec) of δN_e capable of detecting density variations smaller than 0.5%.

The sweep parameters and sampling rates as defined in Figs. 2 and 3 for the two Nike-Tomahawk flights were:

$$(V_-, V_+) = (-1.55\text{v}, +3.0\text{v})$$

$$V_B = +2.0 \text{ v}$$

$$T_S = 800\ (10^{-3}) \text{ sec}$$

$$(T_{ON}, T_B) = (100\mu s, 1900\mu s)$$

$$T_i = 90\ (10^{-6}) \text{ sec}$$

III. PRELIMINARY FINDINGS

A synopsis of launch information and Wideband ephemerides are presented in Tables I and IV, with flat-earth trajectory data (preliminary) for the Nike-Tomahawk rockets appearing in Tables II and III. (The nearest space-time correlation between the rocket launches and Wideband passes occurred during the NASA 18.179 flight.)

NASA 18.178 was launched during a moderate precipitation event to obtain control data for NASA 18.179 (and NASA 18.180 which did not carry the P^3 experiment). NASA 18.179 was launched under more energetic auroral conditions.

Each of the rockets had low-altitude, long range trajectories to permit extended monitoring of particle precipitation patterns and sensing of X-ray bremsstrahlung radiating upward from lower altitude source regions.

The electron density profiles determined by P^3 for both launches are plotted against space and time coordinates in Figs. 4-7. The plots are of baseline current, I_B, which can be scaled to electron density as indicated by the values shown at the E-region peaks in Figs. 5 and 7. Until temperatures and plasma potentials are determined over the entire trajectory, the scaling of I_B values to electron density must be considered to be accurate only within a factor of 2.

The values of I_B for each of the two probes on both payloads were hand-read from an analog flight record, with the values from probe #1 and probe #2 being read simultaneously at their same respective positions in the payload spin period. The time grid selected for this preliminary analysis presents the profiles on a macroscale. Final analysis will show spatial resolutions

better than 1 meter on the higher altitude portions of the flight.

The difference in I_B-values between probes #1 and #2 is primarily a result of different probe areas, intentionally selected to accommodate plasma current sampling on different electrometer ranges with different geometric factors. The relative tracking of the profiles for both probes establishes credibility in the relative variations and provides confidence that the relative measurements were not perturbed by wake effects.

IV. COMMENTS

Upon receipt of digital flight tapes, the reduction and analysis of P^3 data will be conducted on a PDP11/10 system allowing for more accurate and detailed presentation of the density profiles and determinations of temperature and power spectra. These calculations will be carried out by a library of computer programs originally developed for the CDC#3100 and presently being converted for the new computer system. Overall program priorities will identify regions of particular interest. For example, the time interval between 39 Min and 41 Min (UT) during the flight of NASA 18.179 appeared in the analog record to be ideally suited for electron temperature comparisons with Chatanika radar. Attention will also be concentrated on the high frequency irregularities indicated on the records (but not shown in the Figures) below 110 km, with the irregularity density appearing greater on NASA 18.178. In these regions, density fluctuation power spectra will be calculated for comparison with candidate plasma instability mechanisms and scintillation power spectra observed on the nearest time-correlated passes of Wideband.

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TABLE I

LAUNCH AND TRAJECTORY SYNOPSIS

LAUNCH (AST) (UT)	NASA 18.178 21 Sept 1976; 2 HR, 52 M, 0 S Day 265; 12 HR, 52 M, 0 S	NASA 18.179 23 Sept 1976; 1 HR, 37 M, 10.9 S Day 267; 11 HR, 37 M, 10.09 S
APOGEE*	230.4 Km	226.2 Km
RANGE*	343.8 Km	352.4 Km
SPIN RATE	5.53 sec^{-1}	4.49 sec^{-1}
Q. E.	72°	72°
AZIMUTH	26°	26°

* Flat Earth Calculation

TABLE II

PRELIMINARY TRAJECTORY INFORMATION (NASA 18.178)*

TIME		AZIMUTH (DEGREES)	ELEVATION (DEGREES)	X (KM)	Y (KM)	Z (KM)
UT	T-PLUS					
12H.52M.0S	0	0.0	0.0	0.0	0.0	0.0
20	20	21.5	88.31	2.48	6.29	16.31
50	50	23.3	64.22	13.52	31.41	70.82
53M.40S	100	23.58	61.24	31.75	72.73	144.58
54M.30S	150	23.71	57.46	50.00	113.84	194.86
55M.20S	200	23.71	52.68	68.89	156.86	224.73
30S	210	23.77	51.66	72.54	164.72	227.58
40S	220	23.85	50.45	76.49	172.99	229.03
50	230	23.83	49.38	79.82	180.66	230.28
56M.0S	240	23.70	48.167	82.89	188.80	230.35
57M.0S	300	23.99	38.93	107.74	242.08	214.03
50S	350	24.03	28.95	123.09	276.10	167.22
58M.40S	400	24.66	16.52	143.45	312.47	101.98

* Launched: 21 SEPT 1976: 2H, 52M, 0 S(AST)
DAY 265: 12H, 52M, 0 s (UT)

TABLE III

PRELIMINARY TRAJECTORY INFORMATION (NASA 18.179)*

TIME		AZIMUTH (DEGREES)	ELEVATION (DEGREES)	X (KM)	Y (KM)	Z (KM)
UT	T-PLUS					
11H,37M,10.9S	0	0	0	0	0	0
31.6	20.7	16.74	66.3	2.1	6.9	16.4
38M, 1.6	50.7	17.33	64.77	10.6	33.9	75.3
29.8	100.7	17.53	61.76	23.5	74.4	145.3
39M,19.8	150.7	17.41	61.41	36.7	116.9	201.9
40M, 9.8	200.7	17.79	53.19	50.6	157.7	221.3
29.8	220.7	17.82	51.0	55.9	173.9	225.6
39.8	230.7	17.84	49.7	58.76	182.6	226.2
49.8	240.7	17.80	48.5	61.1	190.4	225.9
59.8	250.7	17.78	47.18	63.6	198.5	225.0
41M, 9.8	260.7	17.81	45.65	66.5	207.1	222.5
29.8	280.7	18.00	42.74	72.3	222.4	216.1
49.8	300.7	18.59	39.30	80.2	238.3	205.3
42M,39.8	350.7	18.46	28.30	93.2	279.1	158.4
59.8	370	18.27	24.07	96.8	293.1	137.9
43M,59.8	430.7	-	10.12	114.1	333.43	62.9

*Launched: 23 SEPT 1976; 1H. 37M, 10.09S (AST)
DAY 267; 11H, 37M, 10.9 S (UT)

TABLE IV

WIDEBAND EPHEMERIDES ON DAYS OF ROCKET LAUNCHES

UNIVERSAL TIME DAY	HR	MIN	AZIMUTH (DEGREES)	ELEVATION (DEGREES)	UNIVERSAL TIME DAY	HR	MIN	AZIMUTH (DEGREES)	ELEVATION (DEGREES)
265	10	10	26.9	21.8	267	9	45	36.0	20.4
		11	29.4	29.9			46	34.7	27.7
		12	33.6	40.6			47	42.2	36.8
		13	42.5	55.0			48	55.8	47.8
		14	71.7	71.4			49	82.9	57.7
		15	149.3	71.3			50	123.4	58.2
		16	178.12	54.8			51	152.0	48.6
		17	-173.1	40.3			52	166.4	37.4
		18	-168.9	29.5			53	174.22	28.0
		19	-166.5	21.3			54	179.04	20.5
	11	55	12.8	24.8		11	30	16.1	24.6
		56	4.0	32.2			31	9.7	32.8
		57	-10.1	40.1			32	-1.45	42.8
		58	-31.9	46.0			33	-22.7	52.8
		59	-58.7	46.24			34	-57.5	56.5
	12	0	-81.1	40.48			35	-89.0	49.9
		1	-95.7	32.56			36	-106.5	32.4
		2	-104.8	25.02			37	-115.9	29.9
	13	39	12.3	20.51			38	-121.4	22.1
		40	.93	24.0		13	14	13.7	20.1
		41	-12.7	26.2			15	3.3	24.4
		42	-27.3	26.4			16	-10.0	27.8
		43	-41.3	24.6			17	-25.5	29.4
		44	-53.28	21.3			18	-41.3	28.4
							19	-55.3	35.3
							20	-65.53	21.1

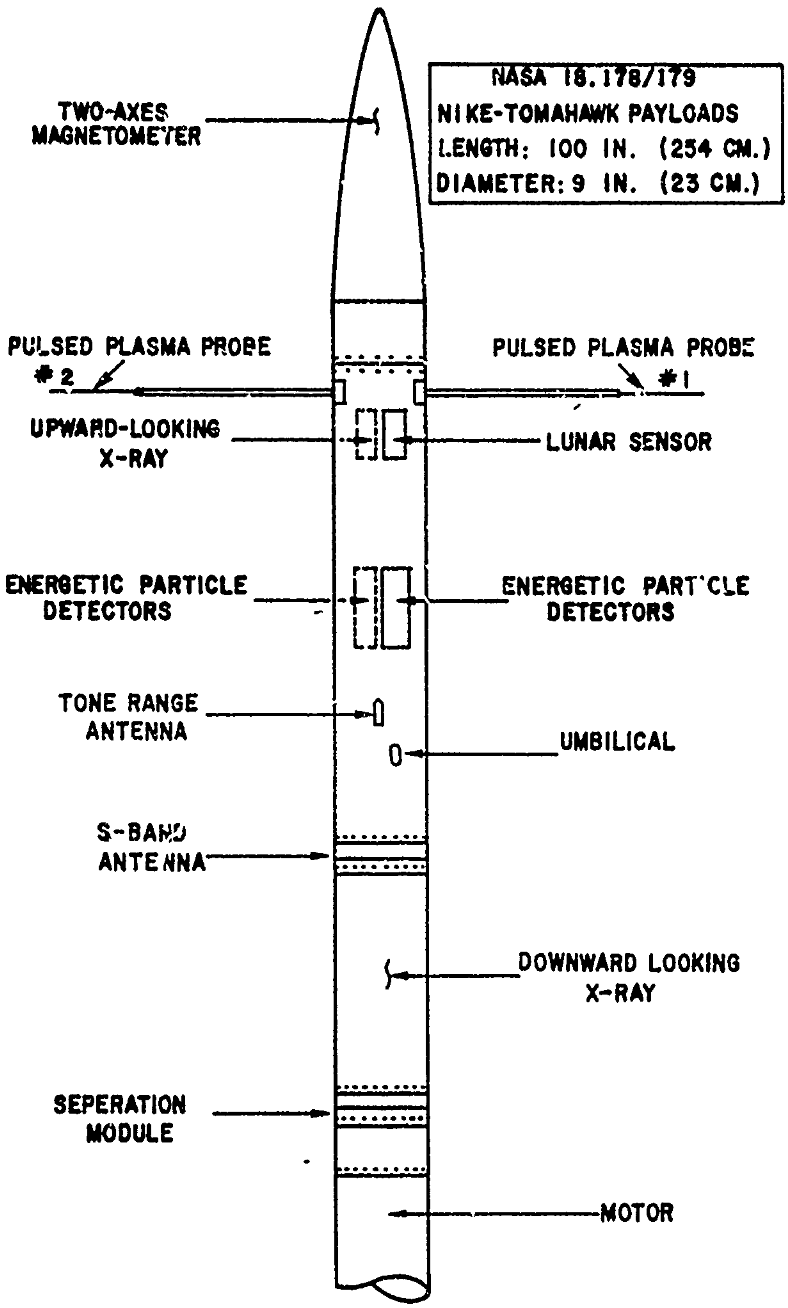

Fig. 1 — Rocket payload configuration for NASA 18.178 and NASA 18.179

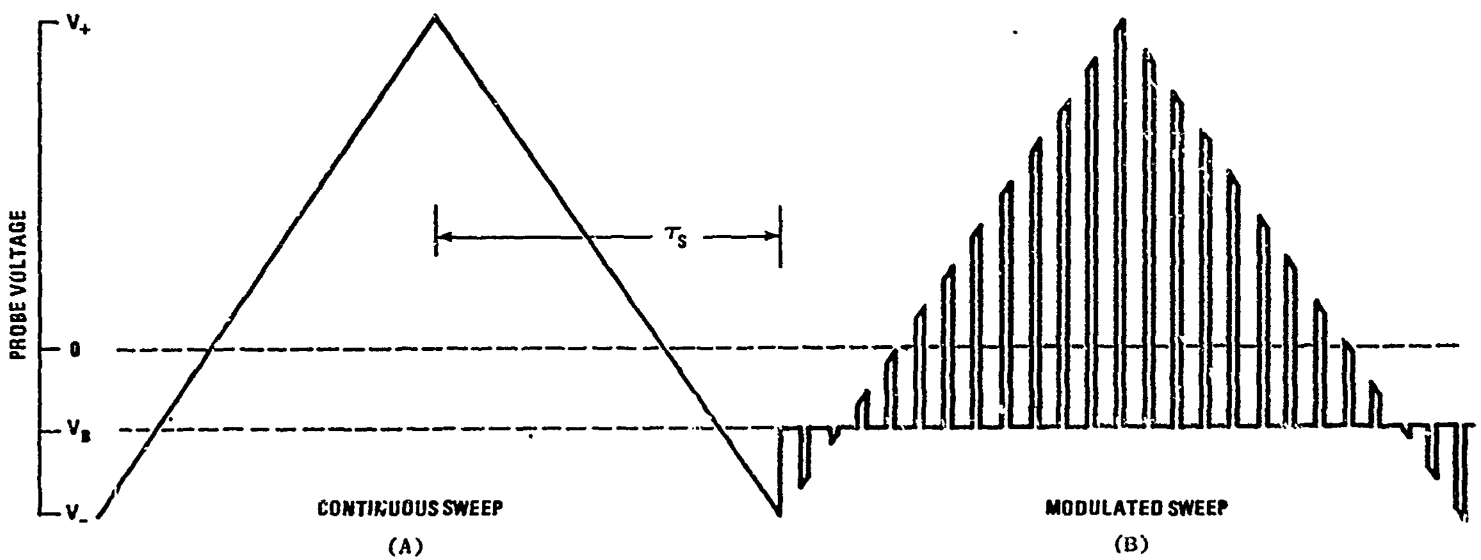

Fig. 2 — Continuous and pulsed modes of operation. (A) represents the conventional approach, while (B) shows the modulated sweep utilized in the P^3 technique

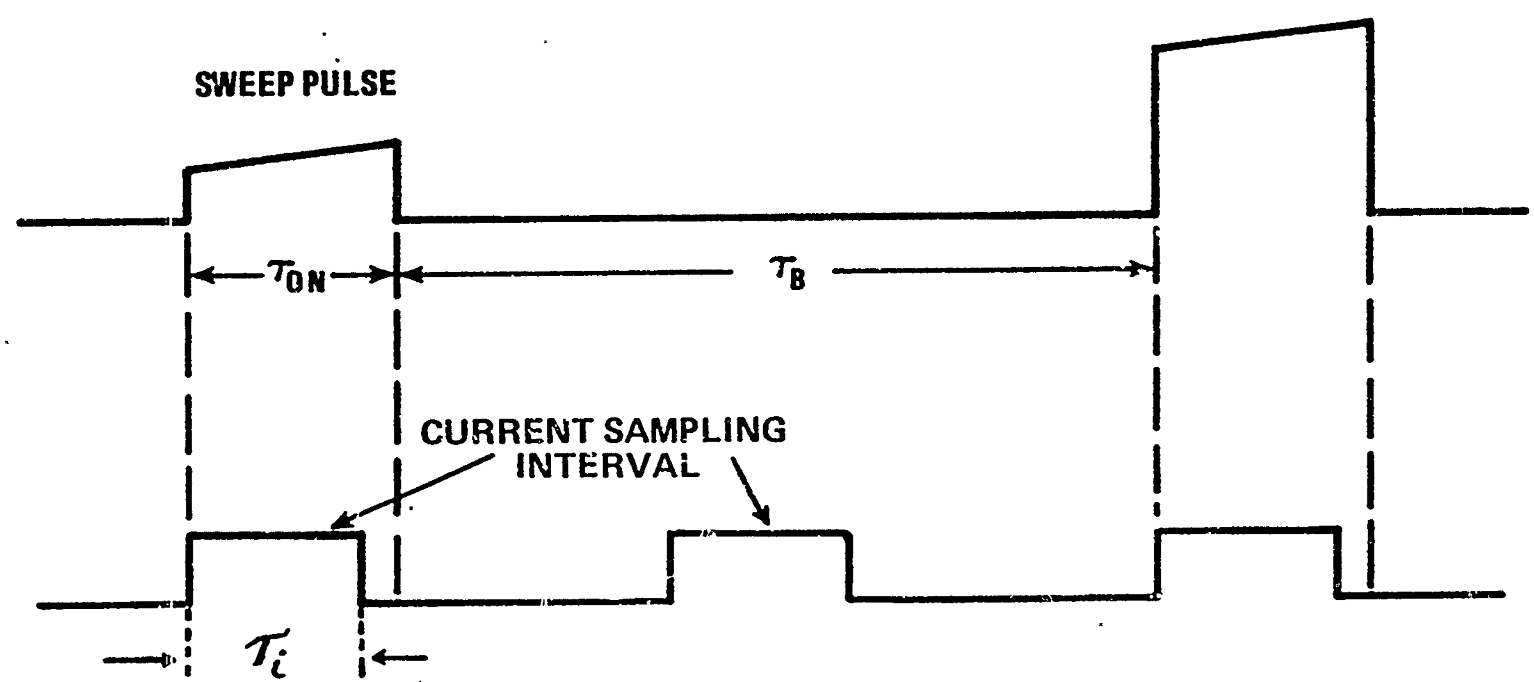

Fig. 3 — Expanded time scale presentation of adjacent sweep pulses (from Fig. 2) showing sweep pulse and interpulse current sampling intervals. (τ_{on}, τ_B, τ_i = (100 μs, 1900 μs, 90 μs.)

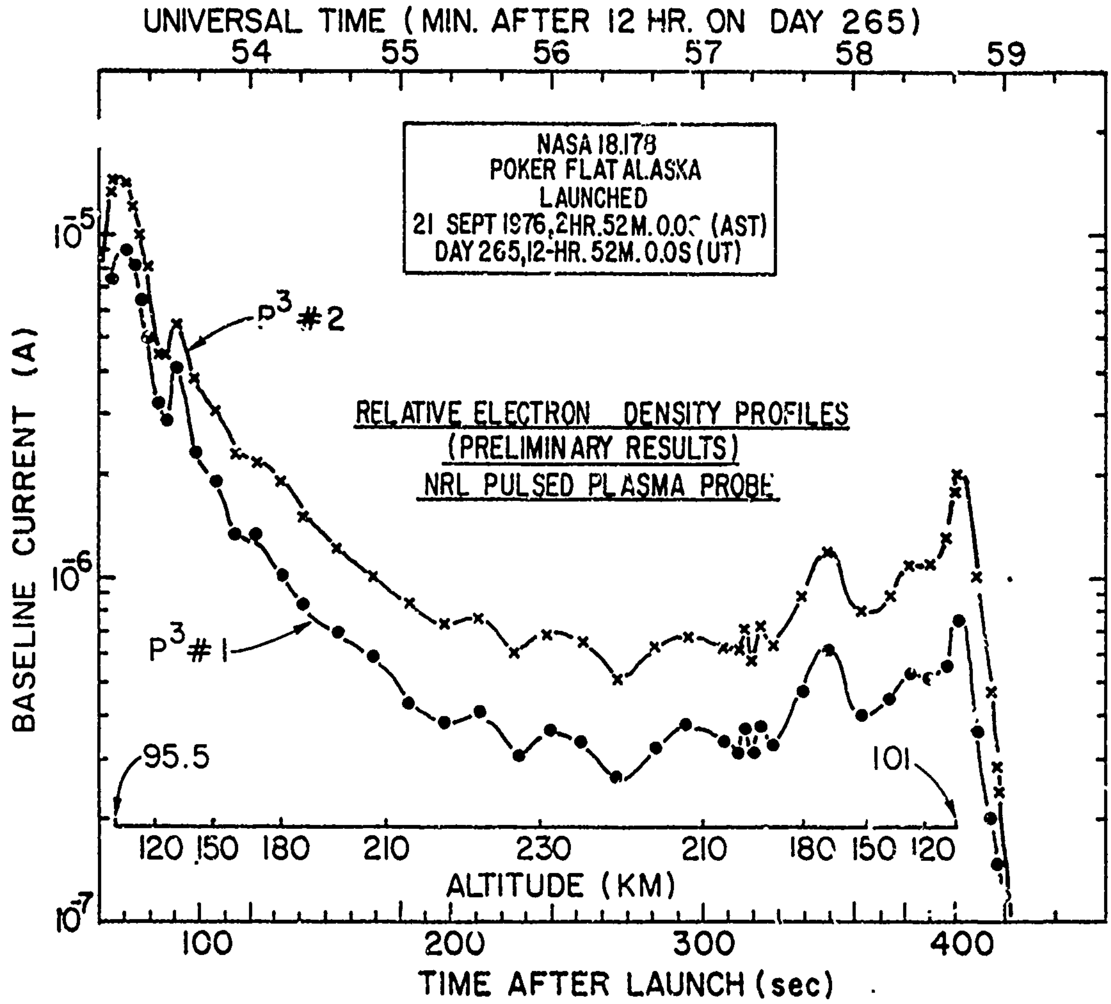

Fig. 4 — Time-dependent presentation of electron density variations as measured by P^3 baseline current I_B sampling on NASA 18.178

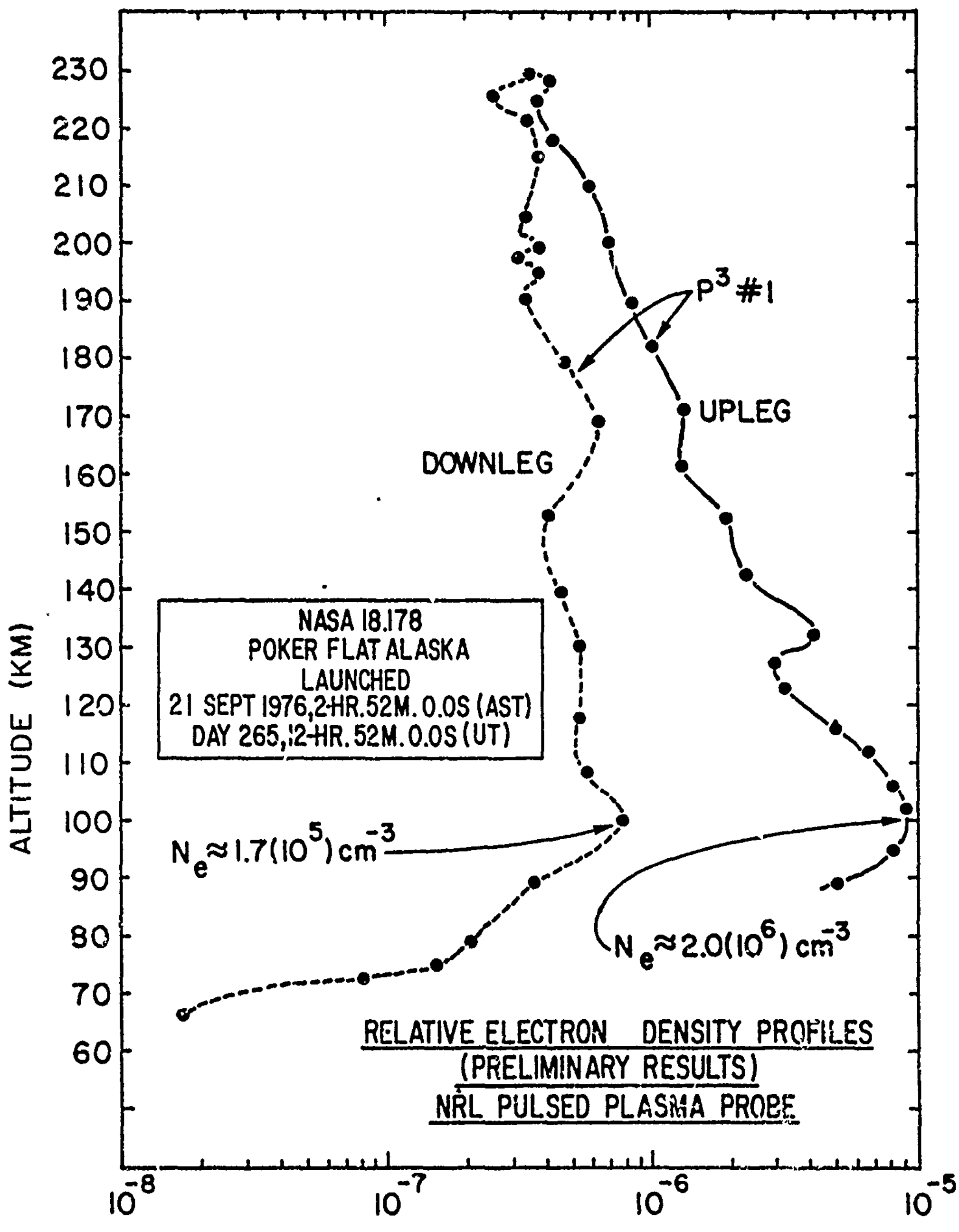

Fig. 5 — Altitude profiles of relative electron density as measured by P^3 baseline current I_B sampling on NASA 18.178

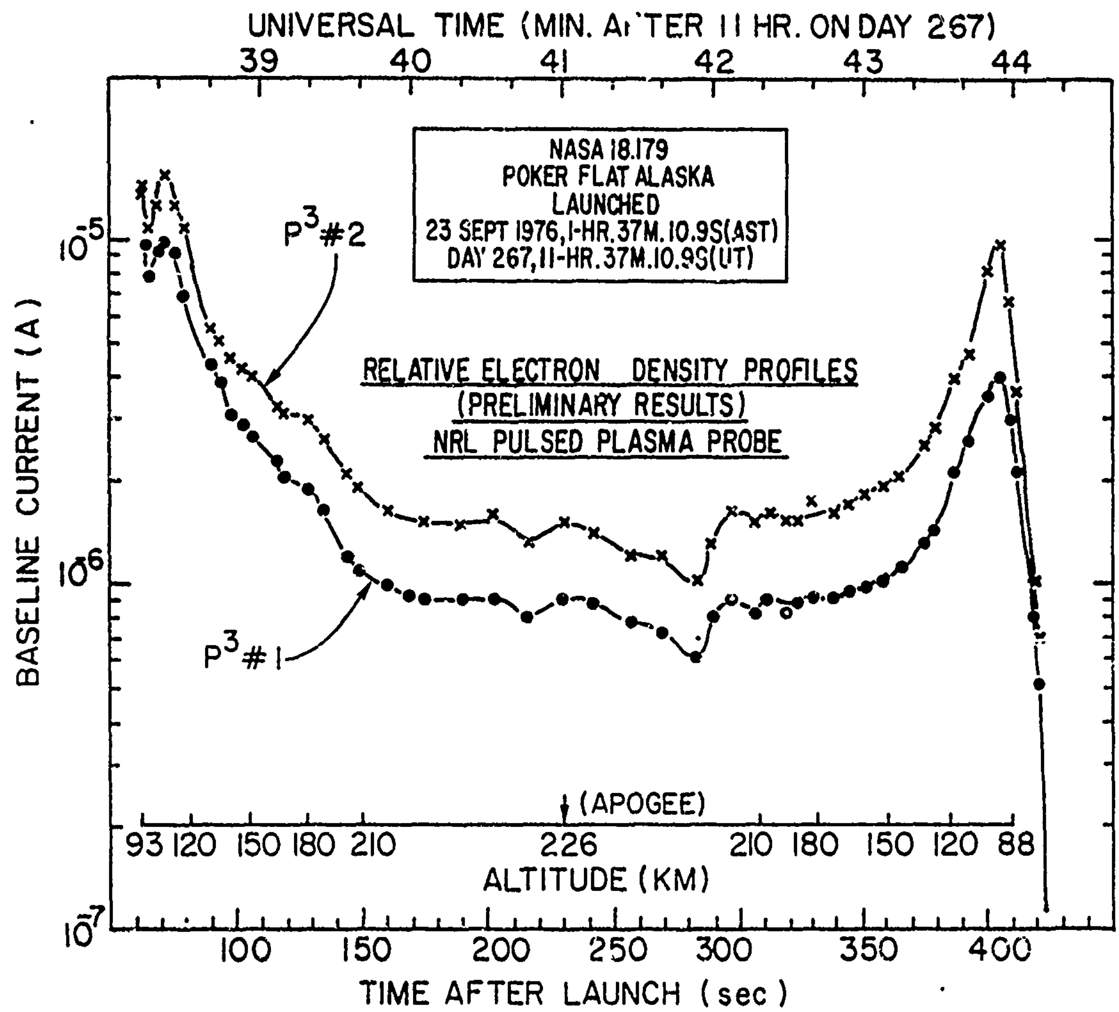

Fig. 6 — Time-dependent presentation of electron density variations as measured by P^3 baseline current i_B sampling on NASA 18.179

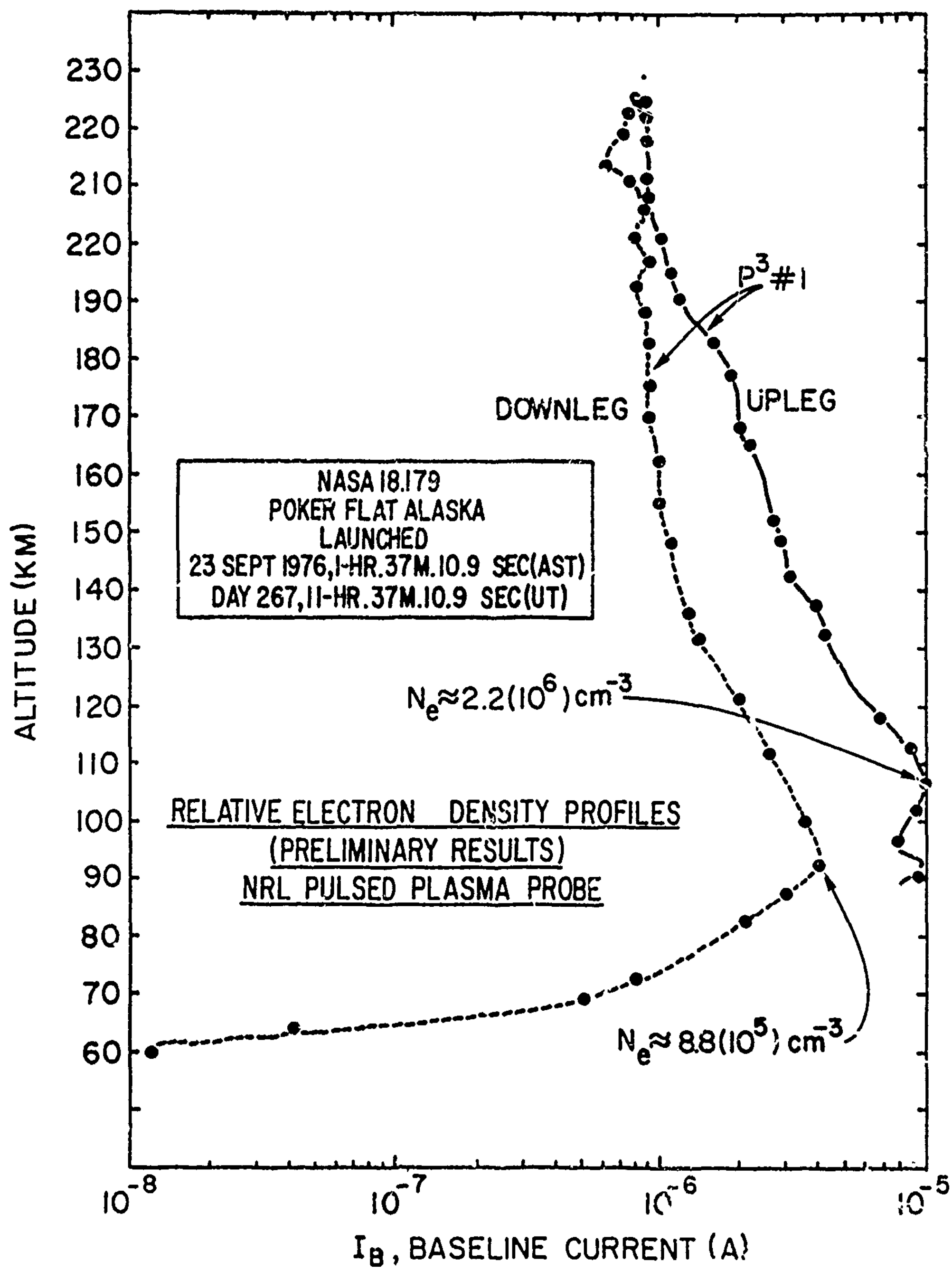

Fig. 7 — Altitude profiles of relative electron density as measured by P^3 baseline current I_B sampling on NASA 18.179